BV-NNET User manual

V0.2 (Draft)

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1. Introduction 2
2. Installation 2
3. Prerequisites 2
3.1. Image file format 2
3.2. Retrieving atmospheric data 3
3.2.1. Using MODIS data 3
3.2.2. Ozone over your house 3
3.2.3. Aeronet network 3
4. Menu Description 4
4.1. Menu 4
4.1.1. Load configuration 4
4.1.2. Save configuration 4
4.1.3. Apply an existing neural network 4
4.1.4. Train a neural network 4
4.2. Image import 4
4.2.1. Prepare image header 4
4.2.2. Import landsat tif images 5
4.2.3. Import spot tif images 5
4.2.4. Generic binary layer stacking 5
4.3. Image export 6
4.3.1. Export binary to geotiff 6
5. How to process an image step by step 6
5.1.1. Spectral bands 6
5.1.2. Index 7
5.1.3. Use as input 7
5.1.4. Scale factor 7
5.1.5. No data value 8
5.1.6. Check the input image consistency 8
5.1.7. Input values 9
5.1.8. Setting the date, location, viewing angles of an image 10
5.2. Atmospheric correction 10
5.3. Canopy model 11
5.4. Output Biophysical variables 11
5.5. Soil spectra 11
5.6. Launch processing 12
6. BV-NNET Output 12
6.1. Report 12
6.2. Maps 13
7. List of changes between v0.1 and v0.2: 13
8. TODO list: 14

1. Introduction

The BV_NNET tool intends to estimate biophysical variables using high resolution remotely sensed images. Four biophysical variables may be estimated with this tool:

- LAI (Leaf Area Index),
- fAPAR (Fraction of Absorbed Photosynthetically Active Radiation),
- fCOVER (fraction of green vegetation cover),
- Albedo

This tool intends to process images coming from various sensors and acquired at different processing level. The BV-NNET tool includes a module to correct images from atmosphere. It is possible to use Digital number images (images that are not calibrated), Top of Atmosphere Radiance images, Top of Atmosphere reflectance images and Top of Canopy reflectance images (Images that are already atmospherically processed).

2. Installation

1. Create a new folder where you will install BV-NNET tool.
2. Copy the BV_NNET_x86.exe file (32 bits) or the BV_NNET_x64.exe (64 bits) file (depending on the Windows version) to the previously created folder.
3. Execute the BV_NNET_x86.exe or BV_NNET_x64.exe file and follow instructions. The BV-NNET tool and the Matlab compiler runtime will be installed.

You can run the BV-NNET tool by clicking on BV_NNET.exe.

3. Prerequisites

3.1. Image file format

The BV-NNET tool uses Envi image file format. The Envi file format is composed of two files : a raw binary image and an header file containing all informations about the image. In case you don't have Envi or you cannot export your images to the envi file format, go to the section 4.2.

The BV-NNET tool uses a binary file containing all the spectral bands of a given image, with a header file accompanying the binary file. The header file is an Envi file format containing information about the number or rows, columns, bands, the kind of interleave, the datatype (corresponding to the envi format, for more information refer to the table on the next page) and the pixel size.

Interleave
BSQ = Band sequential BIL = Band interleaved by line BIP = Band interleaved by pixel

Datatype

1=8 bit byte;
2=16-bit signed integer;
3=32-bit signed long integer;
4=32-bit floating point;
5=64-bit double precision floating point;
6=2x32-bit complex, real-imaginary pair of double precision;
9=2x64-bit double precision complex, real-imaginary pair of double precision;
12=16-bit unsigned integer;
13=32-bit unsigned long integer;
14=64-bit signed long integer;
and 15=64-bit unsigned long integer.

3.2.Retrieving atmospheric data

In order to correct images from the atmosphere, it is required to retrieve information on:

- Water vapor content,
- Ozone content,
- Aerosol optical thickness.

These variables may be retrieved using different data sources listed below.

3.2.1. Using MODIS data

Two MODIS products may be used to retrieve atmosphere characteristics:

- MOD07_L2 (ozone content and water content),
- MOD04_L2 (AOT at 0.55µm)

These products are available at http://ladsweb.nascom.nasa.gov/data/search.html

If the image you wish to process is acquired during the morning, it is convenient to use the MODIS Terra data. You will need to search the MODIS terra atmosphere level 2 data, look for the previously cited files (MOD07_L2 and MOD04_L2) and search for the date and location of your image.

3.2.2. Ozone over your house

Ozone data may be retrieved using the following website. You just have to enter the location and the date of your image.

http://jwocky.gsfc.nasa.gov/teacher/ozone_overhead.html

3.2.3. Aeronet network

The data of the aeronet network are available from this website: http://aeronet.gsfc.nasa.gov/

Aeronet is a network a photometer used to acquire various parameter of the atmosphere. This data may be used get some estimate of the water vapor content and aerosol optical thickness. The optical thickness at 550nm is sometimes not available. You will need to interpolate the nearest values to get an estimate of the optical thickness at 550nm.

4. Menu Description

This section list all the function available from the menu bar.

4.1. Menu

4.1.1. Load configuration

Load a previously saved configuration and restore all the parameters.

4.1.2. Save configuration

Save all the parameters of the current configuration into a file.

4.1.3. Apply an existing neural network

Apply an existing neural network on images to retrieve biophysical variables. In the dialog box asking for a file, select the neural network corresponding to the image you wish to process (the neural network are located in the BV_NNET\Workspace\Report_"configuration name"\Class1\nn_"configuration name"

All the parameters need to be filled before or after selecting the neural network file. Once it is done, you can launch the process. The existing neural network will be applied on images.

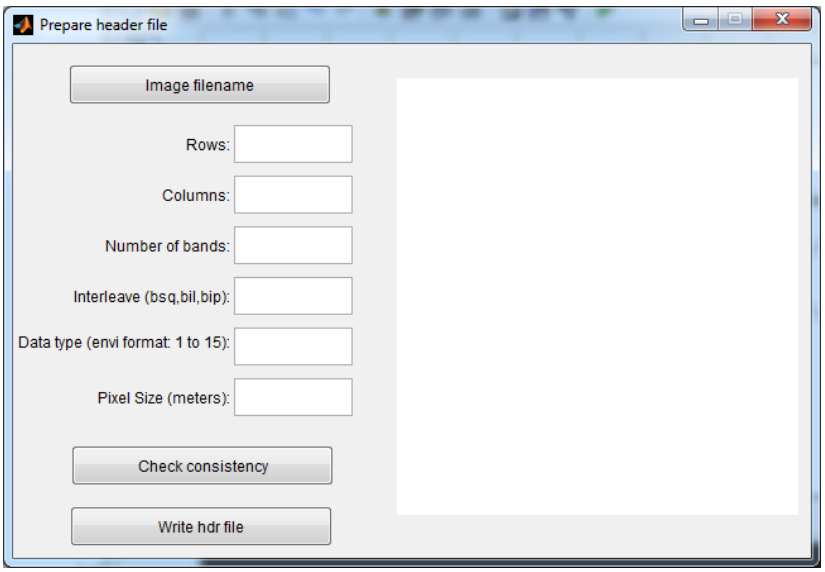
4.1.4. Train a neural network

This function intends to train a neural network for a given configuration. The neural network is trained so that it is possible to use it on another computer.

4.2. Image import

4.2.1. Prepare image header

This tool intend to write an header file(.hdr) containing all the informations needed to read a binary images. In case you do not have the Envi software and you have a raw binary image without the header file, it is convenient to use this tool.



You need to provide the image file name containing the data *i.e.* the binary file (search your file using the dialog box). Then you need to write the number or rows, the number of columns, the number of bands, the interleave, the data type (See section 3.1), the pixel size in meters.

You can check the consistency of all the information by pressing the ”Check consistency” button. This will display a quicklook of the first three spectral bands of your image. If the image doesn’t display correctly, check that all the informations are set correctly.

Once all the informations are filled, you can press the Write hdr file button. This will write the header file and close the dialog box. You can then use this file with the BV-NNET tool.

4.2.2. Import landsat tif images

Landsat images are often available as tif images, particularly the one acquired on the usgs website. This tool intends to convert the tif images into a binary image suitable for the BV-NNET tool. Landsat images are composed of one tif image per spectral band. In the first dialog box, look for the tif images corresponding to the spectral bands you would lilke to process. All images should be the same size, same datatype and covering the same area. Note that it is not possible to use the 8th spectral band of Landsat.

Once you select the spectral bands you wish to convert, you need to provide an output file name. The image is then converted so you can use it with the BV-NNET tool. Keep in mind that the geographic information are not kept during the conversion.

This tool may be used with any other sensor. The only condition to get it working is to have one tif image per spectral band, with the same size, same data type and covering the same area.

4.2.3. Import spot tif images

Spot images may be delivered as tif images and more particularly the SPOTView products. In this case, one tif file contains all the spectral bands unlike the landsat images where each spectral band is stored in a tif file.

This tool convert the tif image into a generic binary image containing all the spectral bands. In the first dialog box, you need to locate the tif file and in the second dialog box you need to give a name to the output image.

It is possible to use this tool with any tif images containing multiple spectral bands, not only with spot images.

Note that the geographic informations are not kept in the header of the output binary file.

4.2.4. Generic binary layer stacking

The BV-NNET tool uses one binary file containing all the spectral bands. In the case you get a binary file for each spectral band, this function may be used to prepare a file suitable for the BV-NNET tool. The layer stacking function intends to stack the generic binary file containing the spectral bands into one file containing all the spectral bands.

In the first dialog box, you need to select all the spectral bands you wish to process. In the second dialog box, provide a name to the output image. All the input spectral bands should be the same size, same datatype, and covering the same area. If it is not the case an error message will appear.

4.3.Image export

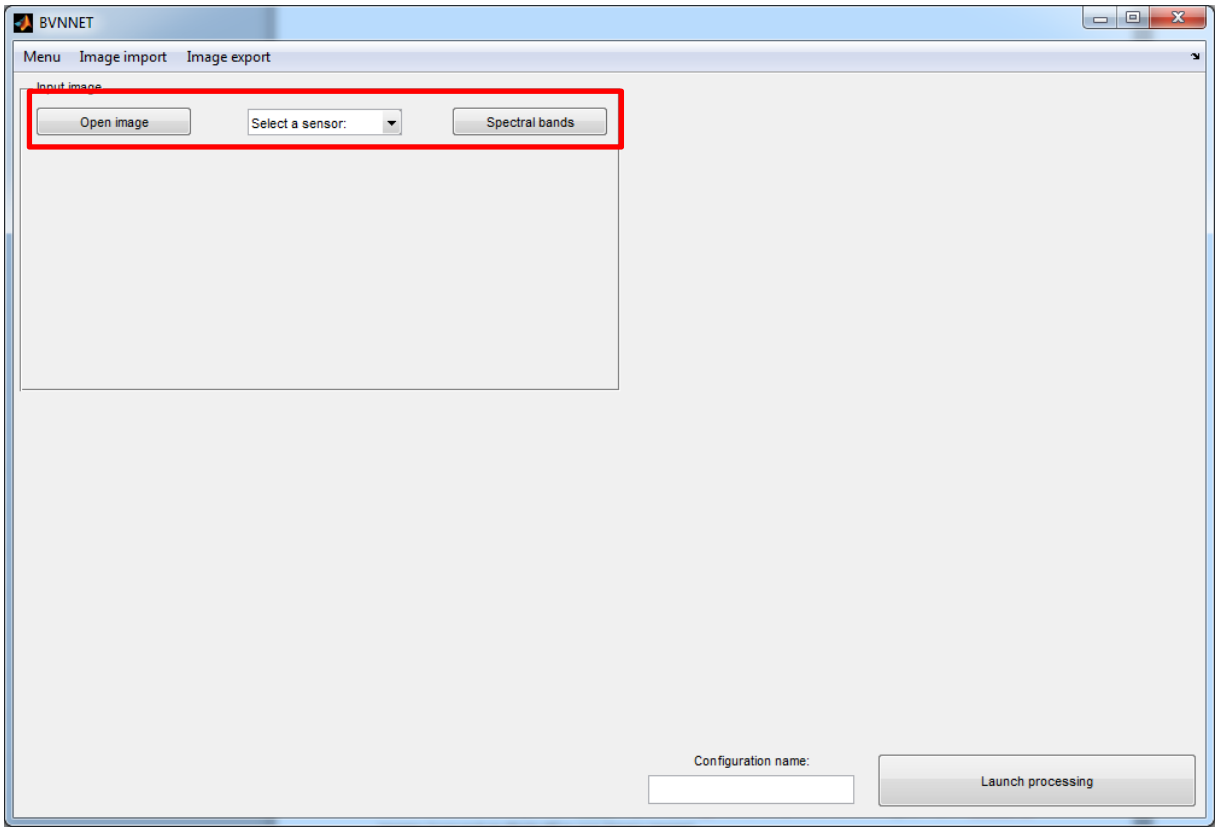
4.3.1. Export binary to geotiff

The output maps of the BV-NNET tool are saved as generic binary file with a header file containing all the specifications of the file. In case it is not possible to read the result in any software, this tool intends to convert the generic binary file into a geotiff file. You need to select one or more output maps located in the Workspace\Image_'configuration name'\ folder. In the second dialog box you need to provide a geotiff image containing all the parameters that corresponds to the image. As an example, if you convert a landsat or spot tif images into a binary file, you will need to provide the input tif file previously converted to a geotif file.

5. How to process an image step by step

Once the BV-NNET tool is launched, the main window appears. You need to provide an input image by clicking on open image. You need to refer to part 3.1 to know which file format is required by the tool. In case you don't have the possibility to get this file format, you can refer to part 4.2 and use one of the Image import function to convert images.

Once the input file is selected, you will have to provide the name of the sensor. Select the sensor you are processing in the listbox.



5.1.1. Spectral bands

Once it is done, click on Spectral bands. A dialog box will appear listing all the spectral bands of the sensor. You will need to provide some information for each spectral bands: Index, Use as input, Scale factor and No data value. Some values are already present in the text box corresponding to the most common cases.

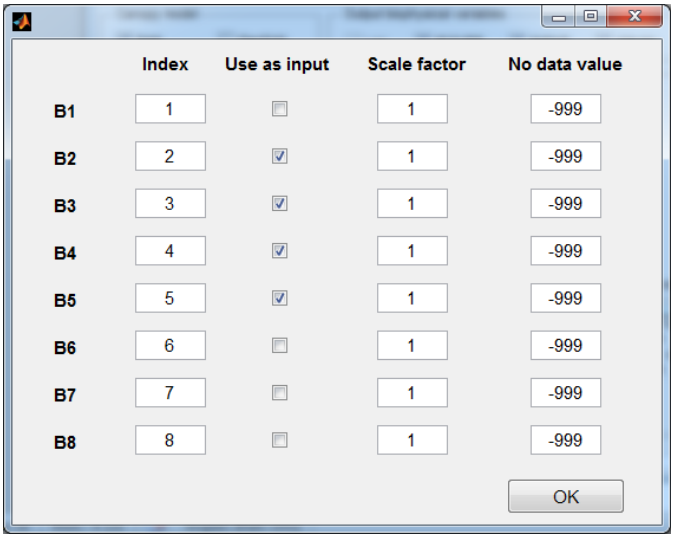
5.1.2. Index

Index corresponds to the location of the spectral band in the file. Usually spectral bands are stored in a file from the shortest wavelength to the longest wavelength but this is not always the case.

As an example, SPOT images are often provided with the near infrared as the first spectral band, the red as the second spectral band, the green as the third and the middle infrared as the fourth. In the "Index" column you will need to provide the position of the spectral band in the file:

Spectral band	Index
PAN	
XS1	3
XS2	2
XS3	1
XS4	4

Another example is a landsat 7 image. The tif images from band 1 to band 5 were converted into a raw binary file using the function import landsat tif in the import image menu. We are not using the first spectral band because it measure reflectance in the blue domain. The configuration is the following:



5.1.3. Use as input

The second column 'Use as input' intends to select which spectral bands will be used by the model to estimate biophysical variables. You need to check the box of the spectral bands that will be used.

It is common not using the blue spectral bands because of the sensivitiy of the blue spectral domain to atmosphere. The thermal bands should not be used as they are not directly related to fCOVER, fAPAR, LAI and Albedo.

5.1.4. Scale factor

When data are saved using a multiplier (in order to save space on hard drive), the data should be scaled by dividing the values with the same scale factor. By default, the scale factor is set to 1. As an

example, if you need to divide input values by 10000 before processing the data, you will need to provide this scale factor in this column.

The scale factor is used to divide input values so that: *output=input/*scale factor

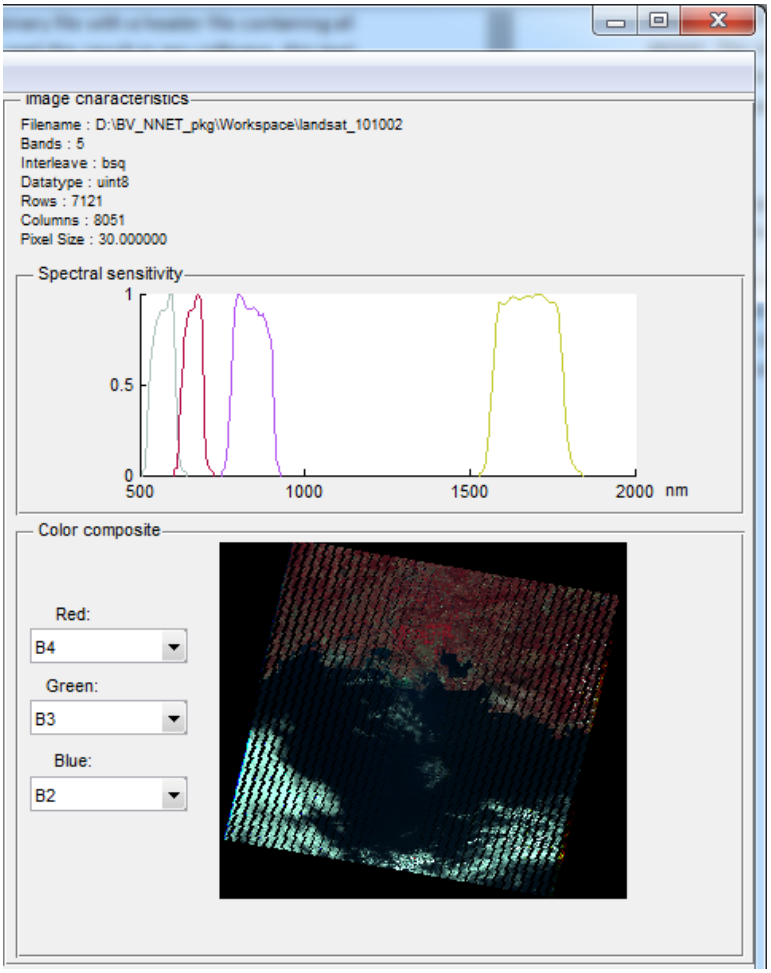
5.1.5. No data value

The no data value is useful just for the color composite that will be displayed on the main panel. If there is no values to define, you can leave the default value.

5.1.6. Check the input image consistency

Once all the information concerning the image, the sensor and the spectral bands are defined, the panel on the right of the main window will show some information about the image (name of image, number of bands, datatype, rows, columns…). The spectral sensitivity of the spectral bands used as input to the model are plotted and a color composite is displayed on the lower right corner of the main window.

You can select the spectral bands used for the color composite. The color composite image is just a way to check that the parameters of the input image are correctly set.

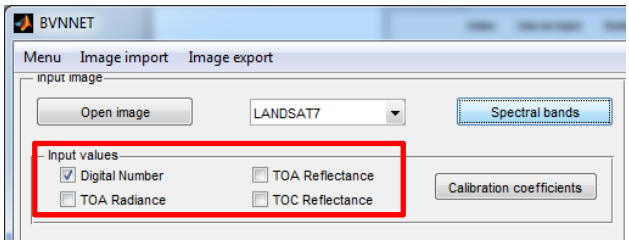


If the input image doesn't display correctly, check all the parameters of the raw binary image in the header file (.hdr)

5.1.7. Input values

The next step consist in defining which kind of values are processed :

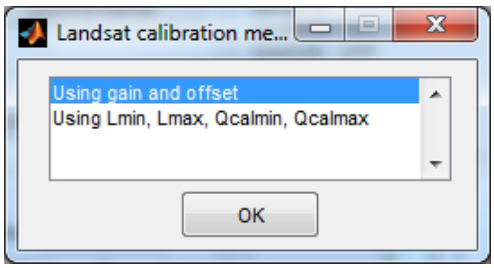
- Digital Number (DN),
- Top of Atmosphere Radiance (TOA Radiance),
- Top of Atmosphere Reflectance (TOA Reflectance),
- Top of Canopy reflectance (TOC Reflectance).



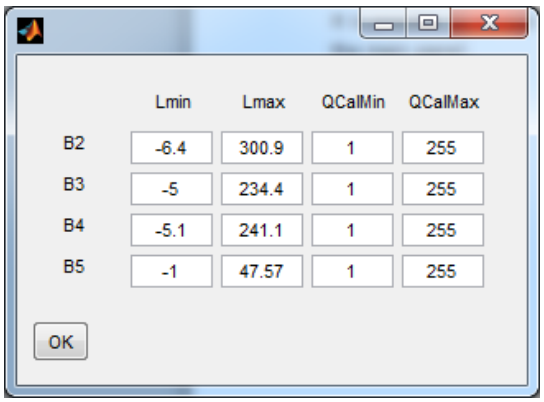
If this setting is not set correctly, the results should be wrong or the software will crash.

In case the data are digital numbers, a window will appear asking for Calibration coefficients.

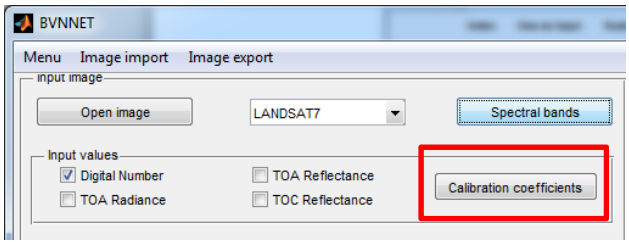
For Landsat images, a first window asking for the calibration method appears. Two methods are used to calibrate Landsat images depending on the institution that provides the images. Check the metadata to find the calibration coefficients named lmin, lmax or gain, offset. If the lmin and lmax values are present, choose the method that uses Lmin, Lmax, Qcalmin, Qcalmax. If only a gain and offset are present in the metadata, select the method that is using the gain and the offset.



Once the method is selected, you need to fill all the calibration coefficients in the new panel that appear and click OK.



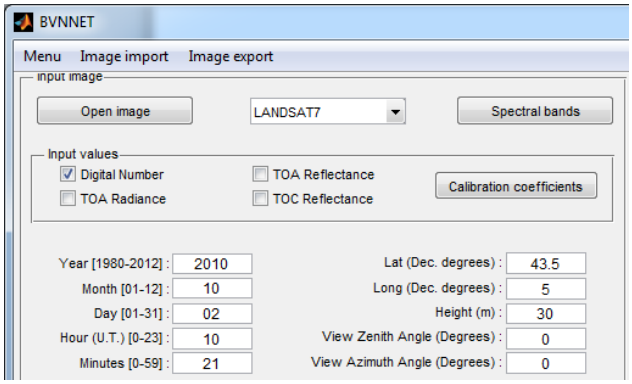
It is possible to modify the calibration coefficients by pressing the Calibration coefficients button on the main panel if needed.



5.1.8. Setting the date, location, viewing angles of an image

The date, location and viewing angles need to be set correctly. It is mandatory to fill all this information according to the values found in the metadata accompanying an image:

- Year of acquisition,
- Month,
- Day,
- Hour (in Universal Time)
- Minutes.



On the right, the location of the center of the images needs to be set: latitude and longitude.

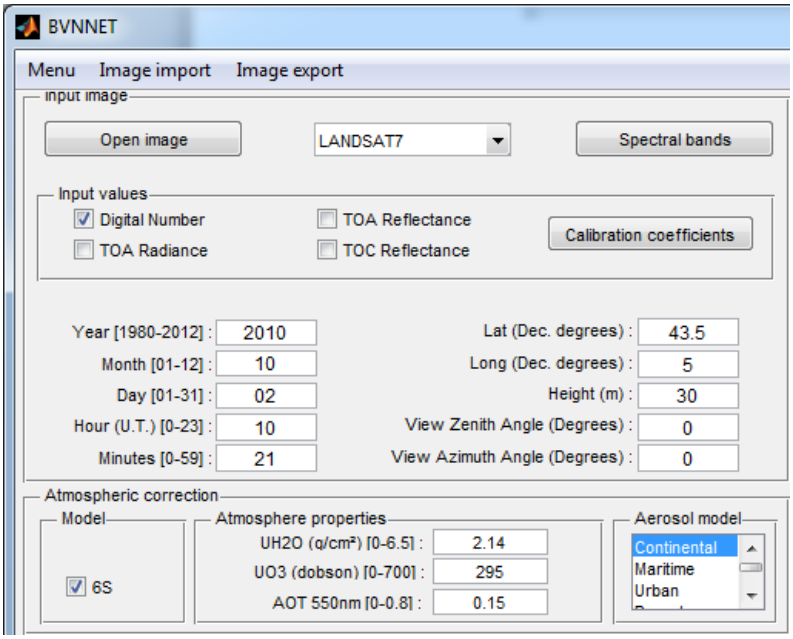
The elevation of the image should be set in meters. This is the mean elevation of the image.

Check the metadata to find the View Zenith Angle and View Azimuth angle. For Landsat images, this parameters is not available, landsat is observing the earth at nadir (0°) and there is no azimuth angles. For all other sensor, check the metadata of the image.

5.2.Atmospheric correction

In order to complete the atmospheric correction, 3 informations are needed:

- The water content of the atmosphere (g/cm^2),
- The ozone content (Dobson),
- The aerosol optical thickness (unitless).



Check the part 3.2 to know how to retrieve this data.

Choose between the 6S and SMAC model. For some sensors, it is not possible to use the SMAC model. The most common option is to use the 6S model.

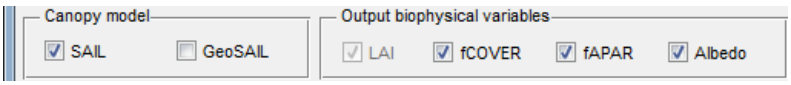
The aerosol model corresponds to the type of aerosol present in the atmosphere. The most common option is to use the continental aerosol model. The maritime aerosol model may be useful on coast but it is most common to use the aerosol model.

5.3.Canopy model

Two canopy radiative transfer models may be used with the BV-NNET tool: SAIL and GeoSAIL. In most cases it is recommended to use the SAIL model. You can use the GeoSAIL model if you are processing an image with row crops or trees.

5.4.Output Biophysical variables

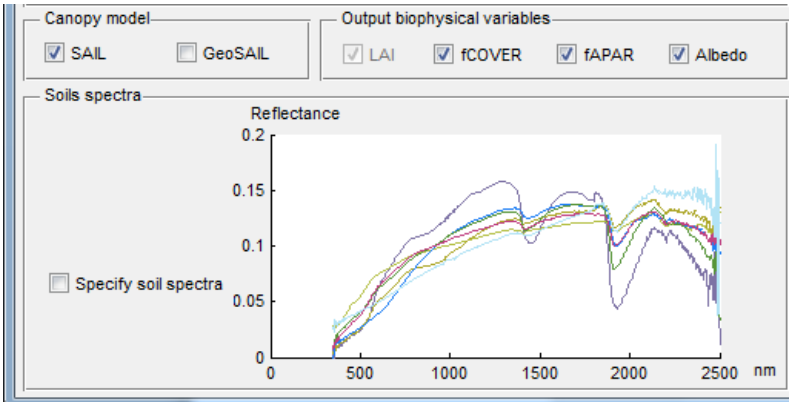
The BV-NNET tool produces 4 biophysical variables: LAI, fCOVER, fAPAR, Albedo. You can choose to estimate all this variables. The LAI is computed by default.



5.5.Soil spectra

The canopy model requires the soils spectra. By default, some soils spectra are already selected and may be appropriate for most study sites.

It is possible to use others soil spectra corresponding to the study site by clicking on Specify soil spectra. The input soil spectra should be either a matlab structure file or a csv file. The csv file should contain in the first column the wavelength in micrometer and the next column should correspond to the soil spectra. You can use as many spectra as you want.



5.6.Launch processing

Once all the informations are filled, a name should be given to the present configuration. This name will be used to create the output results and save the present configuration to a file. Then you can launch the process.

6. BV-NNET Output

All the outputs of the BV-NNET toolbox are stored in the Workspace folder where you install the BV-NNET tool. For each processed image, 2 folders are created:

- Report_"configuration name"
- Image_"configuration name"

6.1.Report

The report is the folder where all the output figures are saved and where you can find the neural network.

In this folder, the following outputs are saved:

- **Neural network performance**

The theoretical performance of the algorithm are saved under Report_"configuration name"\Class_1\Pref_"Biophysical variable".png

Theoretical performances allow checking whether no major problems occur during the training process and provide a first glance on the capacity the algorithm to access the six considered surface variables. The theoretical performances of the networks are evaluated over the test data set which is a fraction of the simulated training data base not used in the calibration of the neural networks. It consists mainly in computing simple statistics such as RMSE values and exploring the dependency of residuals on the variable itself.

- **Distribution and co-distribution of input variables**

Distribution and co-distributions of the input soil, canopy and leaf characteristics used to populate the training data base may be found in the file Class1\Learn_Data_Base\Matrix_Law.png

- **Distribution and co-distribution of simulated reflectances**

The distribution and co-distribution of the reflectances simulated by the model for each spectral band are saved in the file Class1\Learn_Data_Base\Matrix_Reflectance.png

- **Distribution and co-distribution of output variables**

The distribution and co-distribution of the simulated variables are saved Class1\Learn_Data_Base\Matrix_Variables.png

This plot shows the relationship between the output variables (the variables that are simulated by PROSPECT and SAIL or GeoSAIL.

6.2.Maps

The output biophysical variables maps are saved to an envi file format under the folder Image_"configuration name". You will also find an histogram of each biophysical variable map. This histogram allow to check quickly the consistency of the results.

7. List of changes between v0.1 and v0.2:

- Adding the polder sensor
- Make the scale factor and calibration coefficient buttons visible when opening a configuration file
- Initialize graphics when new spectral sensivity or a new soil data file is used
- Modify a bug when the first band index is not equal to one
- Remove the Add_NNT_XlsFile function
- Add 2 functions to import tiff files : Import spot tif files (multiple bands tiff image), Import landsat tif images (convert multiple tif in one binary image)
- Add a function to export envi binary biophysical variables to tiff files
- Add a progress bar when applying the neural network and various messages to know if the process is running
- Removes warning when a folder already exist
- Add an option to switch between SAIL and GeoSAIL canopy model.
- Use of the SAIL model by default
- When the GUI is used, some csv files are used instead of xls file to avoid using excel.
- Modify the memory management of the image processing functions : band_orders, scale_image
- Adding output images and histogram in the report
- Remove the scale_image function (If a scale factor is used, it is directly used in the corr_atm and Macro_Appy_NNT functions
- Add a scale factor to the output reflectances and variables
- Add the possibility to process just one biophysical variable at a time
- The LAI is a default variable,

- Warning message and confirmation when the main window is closed
- Add the colour composite section, allow the user to choose which spectral band are used for the colour composite
- Add a new gui to select spectral bands used for processing, give the index of the band in the file, the scale factor and no data values
- When the BVNNET tool is started, only the three first parameters are shown (open image, sensor and spectral bands)
- The colour composite is displayed considering the no data values
- Add a layer stacking function to stack generic binary files with the same size and data type
- Adding the possibility to use csv file as soils spectrum
- The string from the text box are saved when the launch button is pressed, it avoids a lot of mistake when saved configurations are restored (the string that are changed are not saved if the string is saved inside a callback)
- Create a new variable out_scale_factor to scale output TOC reflectance instead of using the Param.scale_factor variable.
- Delete the configuration name when an old configuration is loaded
- When the load configuration function is used, all parameters are bring back correctly
- Add a warning message when the name of the configuration already exist to avoid overwriting the data
- When the program is closed, the process is not launched
- Remove the menubar from figures
- Modifying the octave to neural network toolbox so that it is compatible with matlab.
- Use the octave neural network toolbox for the compiled version of the program

8. TODO list:

- Add a message to inform the user that the process is finished
- Remove the configuration name and launch processing dialog box at the start of the program.
- The solar irradiance needs to be computed considering the atmosphere and not the exo-atmospheric irradiance for the calculation of albedo
- Add the emissivity calculation
- Use text file to save the configuration
- Remove the no data values when applying the neural network
- Add an option to use the same input database
- Adding an option to choose which output should be saved (calibrated images, reflectance images …..)
- Add an option to use the NDVI or some other indices as inputs of the neural network
- Add dialog box to change the Geosail input parameters (HsD and Crown cover directly from the GUI)